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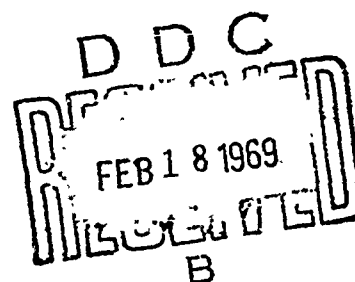
AIR FORCE CAMBRIDGE RESEARCH LABORATORIES

L. G. HANSCOM FIELD, BEDFORD, MASSACHUSETTS

**AFCRL Space Science Research
During 1968**

**(Annual Report to the Space Science Board of the
National Academy of Sciences for
Submission to COSPAR)**

Edited and Compiled by
A. McINTYRE
M.S. TAVENNER, MAJ, USAF



**OFFICE OF AEROSPACE RESEARCH
United States Air Force**



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DEPUTY FOR TECHNICAL PLANS AND OPERATIONS

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OFFICE OF AEROSPACE RESEARCH
United States Air Force

Abstract

A summary of the space science organization and facilities of Air Force Cambridge Research Laboratories (AFCRL); its international activities in space science; rockets and satellites launched during 1968; results of experiments associated with the moon, micrometeoroids, energetic particles and magnetic fields, upper atmosphere physics, meteorology, geodesy, and gravity; planned research in 1969; and a space science research related bibliography are included. The definition of space science for the purpose of this report is limited to in-situ observations and measurements using the broad definition of space.

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AFCRL Space Science Research During 1968

**(Annual Report to the Space Science Board of the
National Academy of Sciences for Submission to COSPAR)**

I. INTRODUCTION

This report was prepared for submission to the Space Science Board of the National Academy of Sciences/National Research Council for use in preparing the United States Space Science Program Report to COSPAR for the Twelfth Annual Meeting, and is limited to AFCRL space science research results which are the product of in-situ measurements obtained through the use of either satellites or space probes. For the purpose of continuity, research results not previously reported to the Space Science Board are included.

The selection of results of AFCRL's space science research for inclusion in this report was guided by Porter's definition of space science as scientific work based on in-situ observations or measurements in space. As a result, space science research conducted at the AFCRL Sacramento Peak Observatory and the AFCRL Prospect Hill Millimeter Wave Antenna Facility, among other space research efforts, was deliberately excluded, although some of the most valuable space research in the world is conducted by scientists at these and other ground-based AFCRL facilities.

More detailed accounts of the space science research results reported herein can be found in the various professional journals and in AFCRL's scientific publications.

(Received for publication 9 December 1968)

2. AFCRL ORGANIZATION FOR SPACE SCIENCE RESEARCH

The Air Force Cambridge Research Laboratories (AFCRL) reports directly to the Office of Aerospace Research (OAR), an operating agency of the United States Air Force charged with the research mission of the United States Air Force.

The mission of AFCRL is to conduct research in those areas of the environmental, physical, and engineering sciences of greatest potential use to the Air Force; conduct specifically assigned exploratory development efforts in these scientific areas; and participate in establishing advanced technologies whose exploitation is in the best interests of the Air Force.

The Commander is the overall AFCRL Laboratory Director. The Chief Scientist serves in an advisory capacity to the Commander on scientific matters. The Deputy for Technical Plans and Operations is responsible to the Commander for the actual formulation, planning, establishment, review, and management of all research and development programs assigned to AFCRL, including the allocation of available funds, manpower, and facilities. Through the AFCRL Environmental Consultation Service, technical consultation is provided to the Air Force exploratory development laboratories, development divisions (including their contractors), and other Government agencies in need of such technical support. The Deputy for Logistics is responsible to the Commander for the formulation of current and future logistics plans and for policies and procedures in the areas of materiel, facilities, and field operations, including engineering and fabrication, technical photography, library, and computation service support to the laboratories. Each Laboratory Director reports directly to the Commander, AFCRL, and is responsible for the management of his specific laboratory. The West Coast Office of AFCRL provides scientific consultation and liaison to Air Force activities located primarily in California.

AFCRL is currently composed of 11 laboratories organized along the lines of the principal scientific disciplines in which they most heavily specialize (see Figure 1). If we apply Porter's definition of space science as scientific work based upon in-situ observations or measurements in space, 8 of the 11 laboratories can be designated as being active in space science research. A listing of the eight laboratories and their specific functions follows.

2.1 Aeronomy Laboratory

The Aeronomy Laboratory performs and supports research and assigned exploratory development of the physical and chemical properties of the earth's upper atmosphere. It also participates in and supports exploratory and advanced development efforts of the Air Force involving upper atmosphere physics.

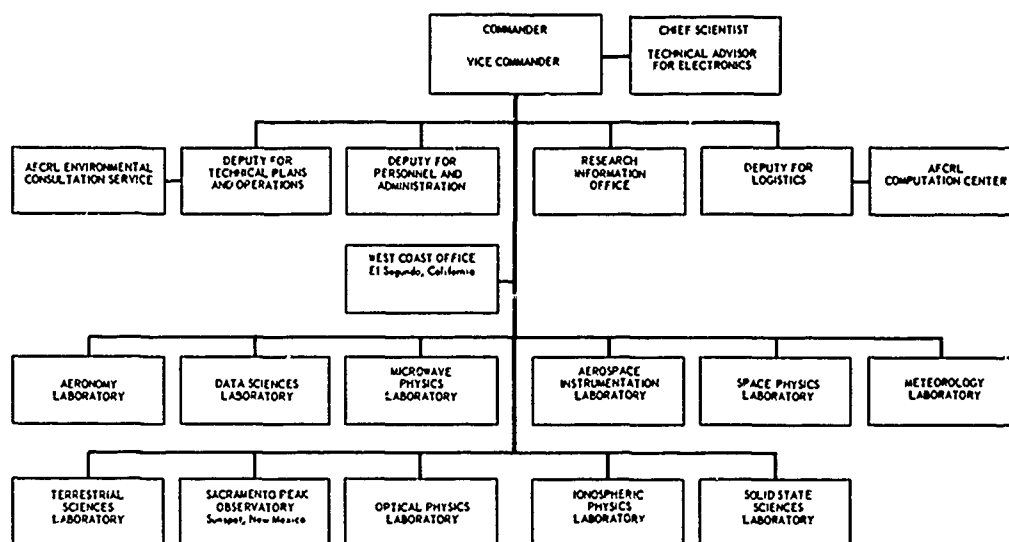


Figure 1. Organizational Structure of the Air Force Cambridge Research Laboratories

2.2 Aerospace Instrumentation Laboratory

The Aerospace Instrumentation Laboratory conducts and supports research and assigned exploratory development directed toward the collection of environmental data through the use of plastic balloons, satellites, and rockets, and toward the development of techniques for measuring and describing the variability of atmospheric parameters. It also participates in and supports specifically assigned exploratory and advanced development efforts of the Air Force involving aerospace instrumentation problems.

2.3 Ionospheric Physics Laboratory

The Ionospheric Physics Laboratory performs and supports research and assigned exploratory development of the properties of the ionized regions of the earth's atmosphere and the propagation of electromagnetic waves through these regions. It also participates in and supports exploratory development and advanced development efforts of the Air Force involving the physics of the ionosphere.

2.4 Meteorology Laboratory

The Meteorology Laboratory conducts and supports research and assigned exploratory development in meteorology. It also participates in and supports specifically assigned exploratory development and advanced development efforts of the Air Force which involve meteorology.

2.5 Microwave Physics Laboratory

The Microwave Physics Laboratory conducts and supports research and assigned exploratory development in the areas of generation, radiation, transmission, and detection of electromagnetic energy and its interaction with ionized and solid media, primarily at microwave frequencies. It also participates in and supports exploratory and advanced development efforts of the Air Force involving microwave physics.

2.6 Optical Physics Laboratory

The Optical Physics Laboratory conducts and supports research and assigned exploratory development concerning the generation, transmission, and detection of optical and infrared radiation and its interaction with the aerospace environment. It also participates in and supports exploratory and advanced development efforts of the Air Force involving optical physics.

2.7 Space Physics Laboratory

The Space Physics Laboratory conducts and supports research and assigned exploratory development regarding solar and planetary atmospheres, interplanetary particles and fields, stellar sources, and space power techniques. It also participates in and supports specifically assigned exploratory and advanced development efforts of the Air Force involving space physics.

2.8 Terrestrial Sciences Laboratory

The Terrestrial Sciences Laboratory conducts and supports research and assigned exploratory development in the earth sciences, including seismology, geodesy, gravity, and geology; acoustics; and selenodesy and planetary gravitational fields. It also participates in and supports exploratory and advanced development efforts of the Air Force involving the terrestrial sciences.

3. AFCL FACILITIES FOR SPACE SCIENCE RESEARCH

AFCL's permanent installations are currently located at 17 different geographical locations and, in terms of land owned, leased, and occupied, cover 944 acres.

AFCL has complete in-house facilities to design and fabricate most sounding rocket, satellite, and balloon payloads, to perform most pre-launch tests and to decommutate and computer-process telemetry data.

One of AFCL's major off-base facilities used to conduct space science research is the Sagamore Hill Radio Observatory in Hamilton, Massachusetts, which includes two large radio telescopes, one with an 84-ft parabolic dish and one with

a 150-ft parabolic dish. The 150-ft dish has been used to receive data from the OV5-1 AFCRL Solar X-ray Monitoring Satellite on an as available basis. It has also been used to conduct ionospheric research by receiving transmissions from various satellites. A Solar Radio Observatory, which monitors solar radio emissions at seven frequencies, including the internationally valuable frequencies of 606 and 1415 MHz, is also located at Sagamore Hill along with other lesser antenna facilities.

3.1 Other AFCRL Major Ground-based Facilities

Another AFCRL ground-based facility used in conjunction with space science research is the Sacramento Peak Observatory, one of the largest and most completely instrumented optical solar observatories in the world. A highly sophisticated vacuum tower telescope for providing detailed observations of the sun—to be used in the development of techniques for the prediction of sun-induced disturbances in the terrestrial atmosphere and space—is nearing completion at Sacramento Peak and will be in operation during calendar year 1969. A 29-ft Millimeter Wave Antenna located on Prospect Hill in Waltham, Massachusetts, is used to conduct solar millimeter wavelength studies at 8.6 mm.

AFCRL also operates permanent sites for the launch of high altitude balloons at both Chico, California, and Holloman Air Force Base, New Mexico.

3.2 Research Aircraft

AFCRL uses six aircraft in the conduct of space science research. These aircraft include: one KC-135 principally instrumented with a Granger sounder, gamma ray monitor, visible photometer, and infrared spectrometer; one KC-135 equipped with a variety of advanced optical and infrared instruments, including radiometers, interferometers, spectrometers, photometers, cameras, and other associated equipment; one C-130 with an infrared scanner, multiband camera, various types of gravity meters, and associated instrumentation; one C-130 with a refractometer, APN-144 Doppler radar, vortex thermometer, and water-content measuring device; one C-130 with an aerosol spectrometer, microwave refractometer, spectroradiometer, magnetic recording equipment, and a horizontal path-function meter; and one C-131 equipped for balloon and meteorological sensing research.

4. INTERNATIONAL ACTIVITIES IN SPACE SCIENCE

4.1 ESRO Rocket Micrometeoroid Collections

Skriver of AFCRL was invited by the Max Planck Institut für Kernphysik to participate in a series of ESRO Centaur rocket flights launched from EsRange,

Kiruna, Sweden. A rocket was launched before, during, and after the peak of the Arietid and Zeta-Perseid meteor showers. The results of these launchings are discussed in Section 5.1.2 of this report.

4.2 Joint Satellite Studies Group Ionospheric Research

The AFCRL Sagamore Hill Radio Observatory observed satellites S-66, ATS-1, ATS-3, and Intelsat IIF3, both as an independent observatory and in cooperation with the Joint Satellite Studies Group. A continuous observation of the synchronous satellites was maintained, and every visible pass of the lower altitude satellites was recorded. The other countries associated with the Joint Satellite Studies Group were Peru, India, Republic of China, Sweden, Israel, Ghana, Kenya, West Indies, Turkey, Norway, Denmark, Greenland, Federal Republic of Germany, France, Spain, Italy, Greece, and Great Britain. The scope of the work included scintillation and total electron content mapping. Detailed studies of particular time periods are being attempted to get a world-wide comparison of scintillation indices and total electron content.

4.3 ISIS-A

Narcisi and Sagalyn of AFCRL will conduct positive ion composition and positive ion density and temperature experiments, respectively, on the Joint Canadian-United States ISIS-A satellite sponsored by NASA and the DRTE, Ottawa. The satellite is scheduled for launch in 1969.

5. AFCRL SPACE SCIENCE RESULTS - 1968

5.1 Moon and Micrometeoroids

5.1.1 BALLOON-BORNE LUNAR INFRARED EXPERIMENTS

Salisbury of AFCRL in cooperation with Murcay of the Denver Research Institute continued experiments using a 60-cm balloon-borne telescope that can automatically acquire and track selected areas on the lunar surface. A circular variable filter with a copper-doped, liquid-helium-cooled germanium detector provided spectral data on infrared emission from the lunar surface between 5 and 13.6 μm . The experimental objectives are to determine the extent to which molecular vibration features (Reststrahlen bands) are present in the lunar IR emission and to utilize any such features in a study of the composition of the lunar surface materials. Of the six flights attempted during 1968 (H68-1, -8, -14, -24, -54, -68) from Holloman AFB, two yielded spectral data from 12 different areas on the moon. Early results that indicated a rather strong spectral feature at 7 μm and a much

weaker feature at $9\text{ }\mu\text{m}$ have been confirmed. The $7\text{ }\mu\text{m}$ feature may be due to the presence of nonsilicate volcanic sublimates on the lunar surface. The spectra are being interpreted in terms of the frequency peak emission. An initial study has shown that the marias are more basic in composition than the highlands. Spectra from the other areas on the lunar surface are still undergoing data reduction. Plans are being made to continue the program with a third generation 125-cm system now under construction.

5.1.2 MICROMETEOROID ROCKET COLLECTION EXPERIMENT RESULTS

Skrivanek of AFCRL was a guest experimenter on three ESRO Centaur rockets launched from Kiruna, Sweden, on 20 May (ESRO C42/1), 7 June (ESRO C42/2), and 8 June 1968 (ESRO C32/2) at a time of meteor stream activity. The collections are presently being analysed in the laboratory. An initial quick-look analysis showed that no large amount of material had been collected. This, of course, is to be expected based on recent experiments. A careful analysis of the in-flight shadowing collecting surfaces has revealed the presence of a small number of submicrometer-size particles.

Preliminary counts of these particles, which had to be collected during the flight, show a concentration of 10 to 15 particles per cm^2 . A chemical analysis of these particles is underway.

Based on the analysis performed thus far, it appears that this series of rocket flights will provide some of the most reliable meteoroid flux data ever obtained from a particle-collecting rocket.

In-flight shadowing experiments were also conducted on a series of rockets launched from Natal, Brazil. The purpose of these experiments was to evaluate the extent to which meteor streams enhance the flux of cosmic dust entering the earth's atmosphere. Of the four rockets launched, three were recovered, but good data was obtained from only two. The first rocket (AG7.273) launched on 8 August, prior to the peak of the Perseid meteor shower, and the third rocket (AG7.275) launched on 12 August, at the peak of the meteor shower, were completely successful. Initial electron microscopic examination of exposed surfaces shows the presence of a small concentration of submicrometer particles; however, since this data was not obtained from surfaces shadowed during flight, the results must be treated as tentative.

The analysis of the in-flight shadowing collecting surfaces from Brazil has been delayed until completion of the ESRO experiments analysis. But, based on the results thus far, it appears that Skrivanek has been successful in reducing the background contamination problem for collection experiments by means of the in-flight shadowing technique. He is able to establish the presence of particles that were collected during flight. The number of particles collected is considerably less than was reported for the early particle-collecting rockets, but is entirely consistent with recent theoretical estimates of the meteoroid influx rate near the earth.

Furthermore, from the AFCRL experiments it appears that meteor streams do not contribute to any great increase in the influx of meteoroid particles in the micrometer-size range. The small-particle fraction of the meteor stream has apparently been lost, leaving only the larger particles. The larger-particle flux does increase with a meteor shower, but not nearly enough to be collected on a 2 to 3 min rock⁺ experiment.

5.2 Particles and Magnetic Fields

5.2.1 PARTICLES

The Air Force satellite OV1-13 (1968-026A) was launched on 6 April 1968 into a polar elliptic orbit with an initial apogee of 9317 km and perigee of 557 km to conduct the AFCRL particle-detection experiments summarized in Table 1. These detectors were supplemented by a triaxial fluxgate magnetometer capable of resolving the pitch angles of the measured flux to a few degrees.

Table 1. AFCRL OV1-13 Particle-detection Experiments

Type Detector	Particles Detected	Energy Range (MeV)	Number of Energy Bins
Solid State	Protons	0.10 to 1.0	8
Solid State	Protons	0.80 to 6.0	8
Range Energy	Protons	6.0 to 100	8
Scintillator	Electrons	1.0 to 10.0	8
Magnetic Field	Electrons	0.13 to 1.0	8
Electrostatic	Electrons	0.03 to 0.1	16
Field	Protons	0.01 to 0.1	16
Geiger-Müller Counter	Electrons, Protons	{ E > 5 E > 45	Integral

The measurements of 55-MeV trapped-proton fluxes by Filz of AFCRL have continued during 1968 utilizing nuclear emulsions recovered from polar satellites. Relative to 1965-1966 measurements, Filz reports a decrease in flux at about 440 km altitude. This decrease was expected due to solar-cycle-related atmospheric-density increases. The flux vs altitude profile for 1968 is approximately the same as that measured in 1961-1962 before the Starfish event caused redistribution. A complete analysis of the time history of trapped proton fluxes is complicated by the Starfish redistribution, and will require complete and accurate theoretical calculations in conjunction with precision measurements. While these observations favor a model involving significant pitch angle diffusion as a source of trapped protons at low altitude, no adequate theory exists.

During the period of high solar and geomagnetic activity between 22 May and 25 May 1967, Katz and Rothwell of AFCRL observed energetic proton fluxes coming up the magnetic field lines from the earth at high magnetic latitudes ($\Lambda > 70^\circ$). The instrument sampled energies between 240 and 1000 keV. A sharp break in the energy spectrum was observed at 700 keV. The half-cone angle of the flux relative to the direction of B was $\sim 11^\circ$. Because of the peaking of the flux along the magnetic field lines, the existence of a radial polar electric field is suggested. The average electric field value required is 0.14 V/m.

The angular resolution of a silicon solid state telescope on board Air Force satellite OV1-9 allowed the determination of the equatorial loss-cone angle as a function of L. The loss cone determined by Rothwell and Katz fluctuates about the values expected for atmospheric losses alone. There is, however, a pronounced narrowing of the loss cone near $L = 2.8$. The degree of narrowing is correlated with the position of the peak flux in L and its magnitude. This suggests the presence of a source or sink of protons at $L = 2.8$.

The modulation of the trapped proton fluxes in the outer Van Allen belt during the period of high solar activity between 18 May and 7 June 1967 was also studied by Rothwell and Katz from data obtained on OV1-9. Four days after 28 May, the period of maximum solar activity, the lower-energy fluxes in the outer belt were measured to be approximately a factor of 10 higher than their preflare values. This increase decayed slowly during a period of relatively stable K_p so that on 7 June the $240 < E_p < 290$ keV flux returned to the preflare value, but the $320 < E_p < 390$ keV and $430 < E_p < 520$ keV fluxes were still enhanced.

A phoswich scintillator detector flown by Katz on an Atlas pod in December 1961 permitted the evaluation of the pre-Starfish electron and proton fluxes in the inner Van Allen belt. Kuck of AFCRL analyzed the data and found the electron spectrum to be

$N_e(E) = 2.4 \cdot 10^6 e^{-2.6E}$ electrons/cm²-sec-ster-MeV for $0.3 < E < 1.0$ MeV, and the proton spectrum

$N_p(E) = 33 e^{-0.11E}$ protons/cm²-sec-ster-MeV for $1 < E < 10$ MeV. These values were determined at $B = 0.160$ and $L = 1.25$.

Electron precipitation events occurring at auroral latitudes were also studied by Kuck, using 10- to 100-keV particle data obtained by a spherical electrostatic analyzer flown on USAF satellite OV3-1. The frequency of occurrence of such events was highly correlated with magnetic activity. For slowly varying precipitation events when $K_p > 3$, spectra before local midnight were softer than those after local midnight. At high latitudes, enhanced fluxes of electrons were seen only during periods of enhanced magnetic activity. The spectral parameters did not seem to depend upon K_p .

A skyhook balloon carrying an emulsion block and large plastic sheets was launched on 1 July 1968 from Churchill. The balloon reached an altitude of 148,000

ft and remained there for 9 hr and 42 min. The plastic sheets, consisting of Lexan and cellulose nitrate, were exposed horizontally for the study of the charge spectrum and isotopic abundance of very-low-energy, heavy nuclei ($E < 300$ MeV/nucleon). Filz and Fukui of AFCRL will attempt to determine the age of the low energy cosmic rays by measuring the relative abundance of unstable isotopes and very heavy nuclei. The emulsion package was designed to study the energy spectrum of heavies over a wide energy region by using an absorber between two emulsion packages. The results will be compared by Fukui with previously obtained data to determine the solar modulation associated with the solar activity cycle.

The AFCRL OV5-6 is expected to be launched in the second quarter of 1969. The apogee of its orbit is expected to be about 17 earth radii. It has been designed to measure solar radiation outside the magnetosphere. The complement of instruments will cover the following energy intervals for the indicated particles:

<u>Type Particles</u>	<u>Energy Intervals</u>
γ - rays	1 - 2000 keV
protons	0.5 - 100 MeV
alphas	2 - 100 MeV
electrons	> 40 keV

Except for the electron measurement, these energy intervals are broken down into approximately five sub-intervals.

Data from an earlier satellite, OV5-1, were received and are being processed and analyzed. A preliminary report of this work was given by J. B. Gardner, et al., at the April 1968 meeting of the American Geophysical Union in Washington, D. C.

During the last solar cycle, several reports were made of short term variations (within a day) of alpha particles near 2 GV magnetic rigidity, notably by P. Meyer. These changes were relatively small and difficult to explain in terms of geomagnetic impact zones. By taking into account more recent knowledge of the interplanetary magnetic fields (particularly the so-called "garden hose" effect) and making observations in the primary impact zone for 2 GV particles, quasi continuous solar production of these higher energy particles may be confirmed. Yates of AFCRL plans to fly one or two high altitude balloon flights with counter telescopes in 1969 from Churchill for this purpose.

5.2.2 AURORAL MAGNETIC FIELDS EXPERIMENT

An AFCRL Nike Iroquois rocket (AE7.290) was launched on 15 March 1968 at Ft. Churchill, Canada. The payload consisted of a cesium-vapor, total-intensity magnetometer, an electron spectrometer (15 to 200 keV), a proton spectrometer (0.4 to 3.0 MeV), an electrostatic analyzer (0.5 to 15 keV), and an aspect magnetometer. All instruments functioned properly with the exception of the electrostatic analyzer. The vehicle was launched into a 600 gamma magnetic bay during a weak aurora. The data are presently being reduced.

A Javelin rocket (AB19. 287) and a Nike Iroquois (AF7. 292) were launched on 9 November 1968 at Ft. Churchill during a 500 gamma magnetic bay and an auroral breakup. The AFCRL payloads were similar to those on the above-mentioned rocket. The launch times were chosen to allow both vehicles to reach apogee simultaneously. The Javelin flight was successful with all instruments functioning properly. The Iroquois had second-stage ignition failure and reached only 60,000 ft altitude. All detectors were functioning properly, but there were no usable data because of the low altitude.

5.3 Upper Atmosphere Physics

5.3.1 ION AND NEUTRAL COMPOSITION EXPERIMENTS

The Air Force OV3-6 satellite (1967-120A) was successfully placed into a nearly circular polar orbit at 440 km on 5 December 1967 to enable Narcisi and Philbrick of AFCRL to study the latitudinal variations in composition and density and the effects of solar flare perturbations on these parameters. This satellite contains two quadrupole mass spectrometers mounted 180 deg apart along the satellite spin axis. One unit (MSI) is fitted with an accommodation sphere to allow neutral species to attain thermal equilibrium before entering an enclosed ionization chamber. The second unit (MSII) has an ion source exposed to the ambient atmosphere and can be operated as either a neutral- or a positive-ion detector. Each mass spectrometer has a mass range from 1 to 34 amu which is scanned every 5 sec. An on-board tape recorder has been used to obtain data over complete orbits. The major constituents of the neutral atmosphere (O, N₂, O₂, and He) are measured as well as the ionic constituents (O⁺, N⁺, He⁺, N₂⁺, NO⁺, O₂⁺, H⁺, and O⁺⁺). This satellite has been operational for about 1 year and its orbit at present is 352 by 341 km. It is expected to reenter the atmosphere in March 1969. Approximately 80 complete orbits of recorded data were obtained up to March 1968 when the tape recorder signal conditioner malfunctioned. After March 1968 considerable real-time data were obtained. MSII malfunctioned in May 1968 and has not recovered, but MSI is still operating normally. Computer reduction and analysis of these data are well underway.

Air Force satellite OV1-15 (1968-059A) was successfully placed into a polar elliptical orbit of about 160 by 1800 km on 11 July 1968; it contained a payload package that will enable Narcisi and Philbrick to determine the neutral and ionized structure of the atmosphere, especially between 160 and 500 km. In addition to measuring the temporal and spatial variations in density and composition, a primary objective of the satellite was to measure the perturbations in these parameters caused by solar flares and geomagnetic storms. The satellite was designed to have a lifetime of about 3 months; it reentered the atmosphere on 6 November for a lifetime of about 118 days. The two quadrupole mass spectrometers were

similar to those on OV3-6 (1967-120A) but they were programmed differently. The mass spectrometers spun into and away from the direction of motion of the satellite and sat for one spin-period on the mass peak of each of the neutral constituents: N_2 , O, O_2 , Ar, and He. In addition, the mass spectrum was scanned from 1 to 46 amu every fifth spin-period. An on-board tape recorder typically allowed measurements on four perigee passes (500 to 160 to 500 km) per day. On alternate perigee passes, the instrument with the open ion source was switched to obtain ion composition measurements. The ion constituents measured between 150 and 1400 km were: O^+ , N^+ , N_2^+ , O_2^+ , and NO^+ . Both instruments operated well for the entire life of the satellite. The data are undergoing considerable analysis.

A preliminary analysis of the mass spectrometer experiment on OV 1-15 indicates a much larger latitude variation than atmospheric models would predict. For example, the difference between the mid-latitude density for the summer and winter hemispheres at 350 km may be as much as a factor of 3. An appropriate atmospheric model (Jacchia SA0150) would predict a variation of less than 50 percent.

An instrumented Nike Iroquois rocket (AF7.389) carrying a cryogenically pumped, positive-ion, mass spectrometer and cylindrical Langmuir probes was launched from Eglin on 23 July into a 2 MHz blanketing Sporadic E for Narcisi of AFCRL. Two of Rosenberg's chemical release rockets were fired 5 min before the instrumented rocket, and two more followed 5 min thereafter. The results showed the Sporadic E layer to be composed mostly of NO^+ . Metal-atomic ions were present but generally lower in abundance. Of considerable interest was the detection of Al^+ and AlO^+ in such large amounts that they clearly originated from the FMA release. At the altitude of the layer of Al^+ , NO^+ was considerably depleted. This further substantiates earlier results pointing out the importance of the charge transfer process in the ionization of metal-atomic species (Narcisi*, 1968). Further reduction of these data should lend considerable insight into layering mechanisms and ion chemistry.

A Nike Iroquois rocket (AF7.881) containing a cryogenically pumped negative ion mass spectrometer and cylindrical Langmuir probes was launched from Eglin on 17 July 1968. Only Langmuir probe data were obtained; the mass spectrometer malfunctioned.

5.3.2 ATMOSPHERIC STRUCTURE STUDIES USING THE CHEMICAL RELEASE TECHNIQUE

In January and August 1968, nine rocket experiments were conducted by Golomb of AFCRL at Churchill. The rockets carried various chemicals to determine atmospheric temperature, diffusion, density, and atomic oxygen concentration in

*Narcisi, R. S. (1968) On the Creation of Metal-Ion Layers in the E-Region of the Ionosphere, Space Research VIII, North Holland Publishing Co., Amsterdam, 1968, p. 360.

the 90 to 175 km region. All nine rockets and eight of the payloads (on rockets AG7.633, AG7.634, AG7.635, AG7.636, AG8.649, AH7.667, AH7.668, and AH7.685) performed successfully. One chemical release (AG8.648) was unsuccessful due to valve malfunction.

Temperatures were obtained from the AlO vibrational-rotational spectra of fluorescent clouds. Densities were determined from the radii of nitric oxide jets released into the atomic-oxygen-rich layers of the atmosphere. The NO-O reaction renders the jet radius, that is, the contact surface, visible. The luminous intensity of the contact surface was measured with a rocket-borne photometer. This intensity is proportional to the atomic oxygen flux swept up by the jet.

Preliminary results indicate that the atmospheric temperatures and densities follow the appropriate model values within experimental error. The atomic oxygen profile obtained in August 1968 reveals two peaks, one at 96 km and the second at 150 km, with a pronounced trough at 120 km. The number density at the 96 km peak was about $5 \times 10^9 \text{ cm}^{-3}$, which is significantly below the expected value from model densities; the number density at 150 km was $8 \times 10^9 \text{ cm}^{-3}$, which is commensurate to mass-spectrometer measurements and model values.

Two types of ionospheric chemical release experiments were conducted by Rosenberg's group at AFCRL: barium releases to investigate the optical and radio-frequency properties of ionized clouds, and trimethylaluminum releases to measure the neutral wind and wind shear fields.

Four rockets carrying barium payloads were launched from Vega Baja, Puerto Rico, in May 1968. Three of these generated clouds of neutral and ionized barium at about 200 km (AG7.643, AG7.644, and AH8.670). The largest payload had about 100 gram-moles of vaporizable barium. It generated a cloud with a high ion density, and radio frequency returns were obtained at frequencies as high as 40 MHz. It has been observed that larger releases become striated later, and that the onset of striations is accompanied by a change in the characteristics of radio-frequency return signals. The mechanism for the production of the ion cloud is believed to be the excitation of an auto-ionizing level by the absorption of solar photons in the 3000 to 3200 Å region by metastable atoms. Further experiments are planned to determine the relative importance of the metastable levels as a precursor of the ion cloud. A series of releases planned for early 1969 will provide further information on the optimization of payload chemical mixes and release altitudes.

The analysis of data obtained from optically thick clouds is proceeding. Peak and integrated intensities are greater than those previously observed. The clouds were photographed through narrow-band filters at seven wavelengths, enabling the population and distribution of ground-state and metastable atoms and ions and barium oxide to be recorded. Spectra were also obtained which permit the population distribution of all species along a line toward the sun to be monitored as a function of time.

The AFCRL July chemical release experiments at Eglin (AG7.628, AG7.629, AG7.632, and AG7.642A) were designed to measure winds and their spatial and temporal variations in an intense Sporadic E layer. They were carried out in conjunction with simultaneous measurements of electron density and movement by ionosonde and kinesonde techniques by Wright of ESSA and in situ, ion, mass-spectra analyses by Narcisi of AFCRL.

Preliminary analysis of a similar experiment conducted in April 1967 at Eglin showed that neutral-induced ion motions controlled the detailed structure of the ionospheric ion density profiles when the dominant ion was NO^+ , and indicated layering of the metal ion constituents.

A detailed analysis of the vertical neutral winds measured by rockets in January 1966 in Puerto Rico showed: (1) a wavelike spatial structure of 9 km wavelength and a rms amplitude of 11 m/sec; (2) vertical shear of the vertical components, comparable to the vertical shear of the horizontal components; (3) small-scale turbulence almost completely absent; (4) nonlinear terms in the equations of motion had large amplitudes.

5.3.3 UPPER ATMOSPHERIC DENSITY

5.3.3.1 Falling Sphere Rocket Experiments

As part of a continuing effort by Faire of AFCRL to study the variability of upper atmospheric density, temperature, and pressure, successful 7-in. falling-sphere rocket experiments were launched with NIRO rockets from Eglin on 1 May (AH7.177) and 4 September (AO7.913-i) 1968. The 4 September launch was fired about 30 min before the nearest-to-Eglin perigee pass of the OV 1-15 (1968-059A) satellite. The rocket and satellite data are being reduced and analyzed for comparison. Eleven additional falling-sphere rocket payloads are being prepared for launch during 1969. Five of these will be flown as part of the PCA rocket program to be conducted from Churchill in the Fall of 1969.

The reduction and analysis of data was also completed for the five falling-sphere rockets launched at WSMR during January 1967. Faire reports that the density and temperature profiles exhibit some unusual features in the region around 80 km. Density departures relative to the U. S. Standard Atmosphere, 1962, as high as 25 to 50 percent were observed while the corresponding temperature profile shows an increase as high as 70° K in the mesopause. These data are being further analyzed in an effort to establish possible mechanisms associated with the observed departures.

5.3.3.2 OV 3-6 (1967-120A) Satellite Density Experiments

The AFCRL ATCOS II satellite (OV 3-6) is still in orbit at approximately 370 km. Analysis of density results from three cold-cathode type ionization gauges is continuing. From the results it was possible to study quantitatively the magnitude

and time constants of satellite and gauge outgassing, absorption, and desorption. The gauge density values agreed with orbital drag densities from the same vehicle within about 25 percent. The gauge densities fell off more rapidly at high latitudes than predicted by model atmospheres.

5.3.3.3 OV 1-15 (1968-059A) Satellite Density Accelerometer Experiments

The OV 1-15 (SPADES) satellite was launched on 11 July 1968 into a polar elliptical orbit with an initial perigee at 154 km and apogee at 1809 km. It contained several independent experiments for measurement of atmospheric density as well as experiments for solar and geophysical measurements. Density experiments included: (1) an AFCRL triaxial accelerometer system (Champion and Marcos) consisting of three mutually perpendicular single-axis Bell MESA instruments, each using an electrostatically suspended proof-mass that was electrostatically force-rebalanced; and (2) two hot-cathode magnetron ionization gauges (McIsaac), one looking parallel to the ram position of the satellite and another looking perpendicular to the ram. Preliminary results from the accelerometer system show good agreement with data obtained from orbital decay studies. Also, a variation in density of about 20 percent between 8 deg N latitude and 28 deg S latitude was found at 190 km. Atmospheric models predicted a variation of about 1 percent. Initial gauge data indicates that a considerable amount of atomic oxygen absorption occurred within the ram sensor. Agreement with the U. S. Standard Atmosphere Supplements, 1966, is satisfactory if corrections for atomic oxygen are applied. Data analysis is continuing. A major objective in 1969 will be to correlate low altitude density data with solar and geophysical parameters.

5.3.3.4 OV 1-16 (1968-059B) Satellite Density Measurements

The OV 1-16 satellite (CANNON BALL) was launched on 11 July 1968 into a polar elliptical orbit with an initial perigee of 149 km and an initial apogee of 568 km. It contained a triaxial accelerometer system of the same type flown on OV 1-15 for determination of atmospheric density by measurement of the satellite deceleration due to air drag, and a C-band beacon to permit accurate orbital position data. The spacecraft was a 23-in-diam sphere weighing 600 lb (see Figures 2 and 3) and was designed by AFCRL to specifically obtain accurate density data at very low satellite altitudes. Near the end of its 39-day life, data were obtained down to 120 km. Preliminary results by Marcos and Champion of AFCRL indicate densities that are in good agreement with orbital decay data and with appropriate model atmospheres. Orbital decay results were obtained over the whole lifetime. These data show an increase of 10 percent in density at about 130 km, corresponding to an increase in K_p from 2 to 6.

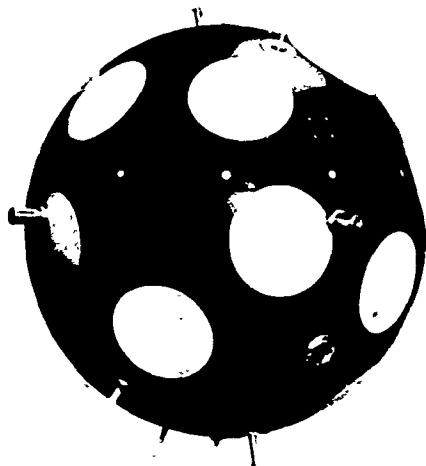


Figure 2. The AFCRL OV1-16 (CANNON BALL) Satellite

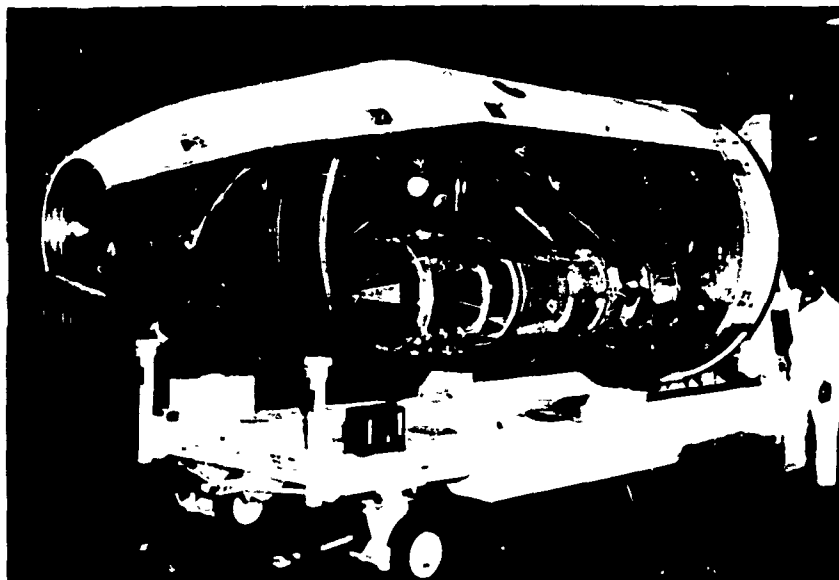


Figure 3. The OV1-16 (CANNON BALL) AND OV1-15 (SPADES) Satellites Shown After Mating With Their OV1 Propulsion Modules Within the Launch Vehicle Heat Shield

5.3.3.5 Inflatable Sphere Atmospheric Density Measurements

Two Nike Iroquois rockets (AG7.571 and AG7.572) carrying inflatable 1-m-diam, instrumented spheres were flown from Kauai on 17 and 23 May 1968 by Faucher of AFCRL, in conjunction with Sandia Corp., to compare various density-sensing techniques (passive sphere, ram pressure, molecular fluorescence). The comparison is not yet complete. Future comparisons are planned between the instrumented inflatable sphere and the grenade technique in early 1969.

5.3.4 SOLAR SPECTROPHOTOMETRY

In a continuing program of rocket observations of solar EUV fluxes by Hinteregger of AFCRL, three spectrophotometers were flown on Aerobee rockets from White Sands on 19 February, 6 August, and 21 November 1968 (AH3.531, AH3.532, and AT3.533). These were designed to obtain measurements at wavelengths ranging from 250 to 1260 Å, and to provide absolute intensities and information on possible long-term temporal variations.

A compact type of solar EUV spectrophotometer for wavelengths from 170 to 1700 Å, consisting of six monochromators with a common scanning mechanism, has been prepared for an early 1969 flight on a solar-oriented section of the OGO-F satellite.

Hinteregger and Hall of AFCRL report that the technique of determining atmospheric structure by analyzing observed atmospheric absorption characteristics at various wavelengths of solar EUV radiation (used previously in rocket experiments at a few geographic locations at maximal heights of 200 to 240 km) was substantially extended by the operation of a solar EUV monochromator aboard the OSO-III satellite, whenever the instrument was set to some suitable fixed wavelength. The main advantages of the satellite technique are: (1) the extension of the height range of useful data to an upper limit of about 450 km; (2) the far greater amount of data for given latitude regions as a function of season and solar activity; and (3) the repeated coverage of different latitudes ranging from equatorial to about 35 deg (N and S). The main disadvantage is the obvious limitation to conditions of zenith angles of ~90 deg in the effective probing region (that is, essentially ground sunrise or

In addition, data obtained from the Hinteregger and Hall extreme ultraviolet spectrometer aboard the OSO-III satellite was used to determine the temporal variations of solar extreme ultraviolet in the wavelength range from 1300 Å to 260 Å over a 6 month period. The measurements give the variation in the flux from the total solar disk, without spatial discrimination of sources across the face of the sun. In the data inspected so far, the variety of forms observed in the solar EUV enhancement accompanying a flare is so complex that only very general statements can be made at this time concerning the magnitudes and time-dependences of solar EUV flares.

5.3.5 AIRGLOW

The analysis by Dandekar of the AFCRL November 1967 (AD3.365) dayglow flight from the equatorial site at Natal, Brazil, is complete. The results, to be published, show that the contribution to $[OI]5577$ dayglow emission comes from three ranges of altitudes: (1) The lower layer is around 95 km, with half emission width of about 23 km and peak emission of about 330 photons/cc. This layer contributes about 40 percent of the total emission and is similar to the one that contributes most of the nightglow emission. The excitation mechanism is of chemical origin. (2) The second layer is in the altitude range of 110 to 150 km. The contribution of this layer is a function of the solar zenith angle at the time of observation. The probable excitation mechanism is the photodissociation of O_2 . (3) The third layer is above 150 km. The excitation mechanism is the process of recombination of O_2^+ and e, and also the excitation of O_2 by photoelectrons. This contributes about 30 percent to the dayglow emission.

Another of Dandekar's experiments to measure the $[OI]5577$ emission in the nightglow was conducted with a rocket (AG8.649) launched from Fort Churchill on 20 August 1968. The analysis of the data is in progress.

5.3.6 ELECTRICAL STRUCTURE OF AEROSPACE

Two plasma probes were flown successfully by Sagalyn of AFCRL on the NASA Injun V Satellite (1968-066B) launched on 8 August 1968. The experiment was designed to measure the flux, density, energy distribution, and temperature of protons and electrons with energies between 0 and 2 keV. The thermal distribution of charged particles on a global scale, the determination of the effects of particle precipitation on the ambient electrical environment, and the measurement of the characteristics of the high latitude, topside ionosphere were among the objectives of these experiments.

An AFCRL ion-attitude-sensing system was included by Sagalyn and Smiddy as part of the OV1-15 payload launched on 11 July 1968. The ion attitude instrumentation was flown as an operational unit, giving the spin axis orientation with respect to the orbit plane. This information was used by ground control as a basis for applying signals to magnetic torque coils in the spacecraft for reorientation of the spin axis. From this experiment the global variation of positive ion concentrations along the satellite's polar orbit was also ascertained. Special emphasis has been placed on the study of results obtained in polar regions.

Two a-c plasma probes of AFCRL were flown by Sagalyn on the NASA OGO-5 satellite (1968-14A) launched on 4 March 1968. The flux, energy, density, and temperature of protons and electrons over the energy range 0 to 2500 eV were measured in the outer ionosphere, magnetosphere, and interplanetary gas.

Two spherical a-c electrostatic analyzers were included as part of the OV2-5 (1968-081A) scientific payload for the study of the temporal behavior of the magnetospheric plasma by Sagalyn of AFCRL. The experiment operated successfully at

power turn on. Subsequently, transmission difficulties were encountered; it is, therefore, uncertain how much useful data will be obtained from this experiment.

On the basis of data from previously reported rocket measurement programs, an analysis of the detailed structure and diurnal behavior of the E-region electron temperatures over the altitude range 90 to 180 km has been completed. The results show that between 100 and 180 km, electron impact-induced transitions among the fine structure levels of atomic oxygen appear to be an important cooling mechanism for electrons. After sunset the electron temperatures decrease rapidly with the development of an isothermal distribution between 120 and 180 km. A sharp temperature gradient is observed between 110 and 120 km; below this level, electron and neutral gas temperatures are equal. Unexpected enhancements of electron temperatures were found between 120 and 160 km 30 min before local ionospheric sunrise. The results were interpreted as due to the influx of conjugate point photoelectrons from the sunlit hemisphere.

In 1969 a positive ion probe will be flown on the ISIS-A satellite for the study of ambient ionization in the topside ionosphere. Four instrumented rockets will also be launched from Fort Churchill for the investigation of auroral electrical processes in the ionosphere E-region. The experiments include measurement of low frequency electric fields, ambient ion and electron properties, and the flux of electrons with energies greater than 40 keV.

5.3.7 POLAR IONOSPHERIC STUDIES

Two Black Brant rockets were launched into Polar Cap Absorption Events at Churchill, Canada, for the continuing study of the disturbed Arctic ionosphere by Ulwick and Pfister of AFCRL. Both rockets contained experiments for the measurement of protons (1 to 100 MeV) and alpha particles (3 to 250 MeV); electron density and temperature; ion density, temperature and mobility; Lyman-alpha flux; photometric measurements of N_2^+ , $H\beta$, O, and the NO_2 continuum; X-ray flux (1-10 keV); and total energy deposition (electrons $E > 10$ keV, and protons $E > 100$ keV). The rocket launched on 10 June 1968 (AF 17. 751) stopped transmitting at approximately $T + 11$ sec, so no experimental data were obtained. The other Black Brant rocket (AF 17. 757) was launched during the 18-19 November 1968 PCA. All experiments worked except for the photometric measurements. This Black Brant is the prototype of six Black Brant rockets to be flown into a PCA event in 1969 from Churchill.

Further analyses of data obtained from the rocket auroral input-output program were accomplished. Results on energy deposition and pitch angle distribution from scintillators flown on an Aerobee rocket have since been analyzed. One scintillator was in an ejected nose tip ($E > 3$ keV) and the other was mounted on the side of the main payload. The side viewing 7 keV scintillator, due to a small precessional

motion of the spinning rocket, viewed pitch angles 90 ± 5 deg to 90 ± 12 deg. When viewing 90 ± 5 deg there was little or no change, but when viewing 90 ± 12 deg the energy changed by a factor of about 3, which is what the ESA data indicated.

Since the ejected nose tip tumbled, pitch angles 0 to 180 deg were scanned by the 3 keV scintillator. For 0 to 180 deg pitch angles there were about 2 orders of magnitude decrease in energy. For comparison, the ESA data on the other rocket were integrated above 3 keV, and a decrease by a factor of about 30 was noted for pitch angles 20 to 160 deg. The flux from the scintillator was relatively constant when the instrument was looking over the upper hemisphere, which was about 50 percent of the time. When looking down (pitch angles 90 to 180 deg), the flux changed very rapidly.

There was good agreement between the two scintillator results relative to fine structure variations. A large variation of the flux occurred around 350 sec when the rocket was at 110 km on the far edge of a rapidly developing arc. The increase in flux was especially noticeable at the lower energies. On the other hand, the Astrobee rocket, 60 km higher and 75 km further downrange at this time, showed no variations in flux. In fact, the short time variations are not correlated at the two rocket positions. A notable exception, however, was the flux increase at 335 sec time of flight of the Aerobee rocket. A corresponding increase was observed on the ESA data at 305 sec time of flight. This was not very noticeable on the integrated energy flux, but it could be seen very clearly at the lower energies. For example, at 3 keV the increase was about 50 percent. This increase in flux was also characterized by corresponding increases in electron temperature and hyperthermal electron flux. A retarding potential analyzer on the Aerobee rocket showed an increase in electron temperature of about 600°C, and hyperthermal (1.5 eV) electron flux about a factor of 4. A retarding potential analyzer on the Astrobee rocket showed an increase by a factor of 2 in the hyperthermal (5 eV) electron flux. It is interesting that this short time variation extended over such a large area and was the only one to show corresponding increases in electron temperature and hyperthermal electron flux.

Retarding potential analyzers of planar geometry were flown on a number of rockets, primarily for the measurement of positive ion currents and electron currents. From the current-voltage characteristic, vehicle potentials, energy distributions, temperatures, and densities can be derived. An examination by Pfister of AFCRL of the spin modulation of certain detectors revealed a sensitivity to electric fields. For instance, a positive ion detector mounted on an arm and oriented in the flight direction showed a spin modulation of the space potential caused by an electric field perpendicular to the rocket axis. Another effect of the electric field is seen as a spin modulation of the saturation current in a side-looking electron detector. So far, observations of electric fields are limited to four rocket flights into auroral

breakup events and to a number of low satellite passes near the magnetic equator at daytime. The values measured normally during the breakup events are about 0.1 V/m. On one special event characterized by a reversal of the vertical magnetic field component during the rocket flight, electric fields up to 2 V/m were observed.

5.3.8 IONOSPHERIC PROPAGATION AND SCINTILLATION STUDIES

The ORBIS HIGH experiment by Mullen of AFCRL was carried into a near synchronous orbit by the OV2-5 (1968-081A) spacecraft. Although the vehicle achieved a satisfactory orbit, the spacecraft is not functioning properly. However, the beacons are operating normally. The experiment consists of two beacons, one at 136.62 MHz designed to operate continuously and unmodulated and the other transmitting on frequencies of 10.004, 15.018, 30.012, and 30.112 MHz. Each transmission is 2 W into a dipole antenna; the lower four frequencies are reduced in amplitude 6 dB, and they alternate each 2.5 sec for 2.5 sec duration.

The ORBIS-CAL experiment was launched on 16 August 1968 but failed to achieve orbit. It is planned again for late February 1969 on OV1-17A. In this experiment a low altitude space vehicle carries 2-W beacons at 8.98 and 13.25 MHz. Apogee will be 462.5 km, perigee 183 km, inclination 99 deg, and battery life about 10 days.

The network of stations near the 70°W and 80°W meridians reported earlier by AFCRL continues. Intensive observations of Explorer 22, ATS-1, and ATS-3 are being made from polar to equatorial latitudes. A detailed examination of data from Sagamore Hill and the Greenland observatories (Thule, operated by AFCRL, and Narssarssuaq, operated by the Danish Meteorological Institute) reveals that the time latitude plot of northern scintillations has a boundary structure somewhat comparable in form to the auroral oval. It is believed that the scintillation structure in high latitudes is initiated by precipitation of low energy electrons. In these studies using satellites at 54 MHz (Transit 4a) and at 40 MHz (Explorer 22) an arbitrary boundary was set up where the scintillation index of 50 percent (at 40 MHz) was reached. At local noon this is observed at 80 deg Geomagnetic North, but it moves away from the pole at other times reaching 60 deg at 0600 and 1800 and 55 deg at midnight, thus differentiating the scintillation region from the relatively narrow latitude auroral oval of precipitated electrons. More data are being collected north of the auroral maximum and are being examined by Aarons, Whitney, and Allen.

Equatorial scintillations are being observed from the Panama stations and, in conjunction with Instituto Geofisico del Peru, from Huancayo, Peru. Over 3000 hr of synchronous satellite data have been taken with only 10 hr showing scintillation. The aim of this study will be to determine the latitudinal extent of the scintillation region in the equatorial zone. The ATS-1 and ATS-3 satellites, as well as Explorer 22, are used in this program.

Nighttime increases in total electron content were observed by Klobuchar along two different oblique paths from the AFCRL Sagamore Hill Radio Observatory by measuring the Faraday polarization rotation of VHF radio waves transmitted from two geostationary satellites, ATS-3 and Canary Bird. Earlier workers, using Faraday measurements from passes of 1000-km-orbit satellites, found a nighttime increase in the mean total electron content over a 2-month period in November-December 1961. AFCRL measurements in the winter of 1967-1968 showed a flat mean nighttime total electron content behavior, but some nights did have sustained increases of over 100 percent of the mean nighttime values. Although measurements along the two oblique paths showed a tendency for agreement, there was not a clear relationship in either time of occurrence or the amount of the increase observed. The sub-ionospheric points below a height of 350 km differed by 10 to 15 deg in longitude and the latitudes were within 2 deg. There was some correlation between the amount of the observed increase and the magnetic K index.

A three-station study of a travelling ionospheric disturbance was made by N. N. Rao, University of Illinois, G. W. Lyon, University of Western Ontario, Canada, and Klobuchar of AFCRL. The travelling disturbance, observed using Faraday polarization measurements from the BE-B 1000-km satellite, yielded a horizontal set of phase velocities travelling northward from 3 to 6 km per sec. The disturbance was interpreted as being a wave travelling at an acoustic velocity of approximately 700 m per sec down the magnetic field line. The disturbance was from 1 to 2 percent of the total electron content and at least 700 km in horizontal extent. No satisfactory mechanism has been proposed to fit this observation.

5.3.9 ATMOSPHERIC OPTICS

The combined AFCRL (albedo) and University of Munich (IR radiometer) balloon experiment, previously flown in 1967, was repeated by Essex and Dearborn on 24 May 1968 (H68-34). Data were recorded for the two experiments. Upwelling radiation flux in 12 wavelength bands between 3900 and 9000 Å was obtained during the entire flight period of 8 hr. These analog data were reorganized into a digital format. A computer program is now being written for formal presentation of the data.

The eight-channel scanning IR radiometer performed well to an altitude of 9 km. The operational sequence ceased at this level so data was obtained only in a single channel for the remainder of the flight. There is a still undefined problem associated with this single channel. Post-flight calibration is being undertaken for comparison with the pre-flight information. This approach should establish the nature of the malfunction.

A multi-purpose balloon-borne experiment (H68-35) was flown by Toolin of AFCRL on 28 May 1968 at Holloman AFB, New Mexico. The vehicle was a 2.01×10^6 cu ft stratofilm balloon that carried a payload of 650 lb to a float altitude of

28.2 km. The gondola supported a biaxial sun pointer that oriented measuring devices in accurate position (± 2 min of arc) with respect to the solar vector. One instrument, pointed directly to the sun, determined water vapor absorption by measuring solar intensity within and outside a near infrared water vapor band. The other measurement system consisted of two spectroradiometers, sensitive to the intensity and polarization of visible radiation. These units were programmed to scan from horizon to horizon through the nadir. One was oriented for the vertical plane determined by the sun and point of observation, and the other for the vertical plane normal to this.

Telemetered data were obtained for 4 hr. Recovery was successful. The system is to be flown again in the first and third quarters of CY69. Its principal features are shown in Figure 4.

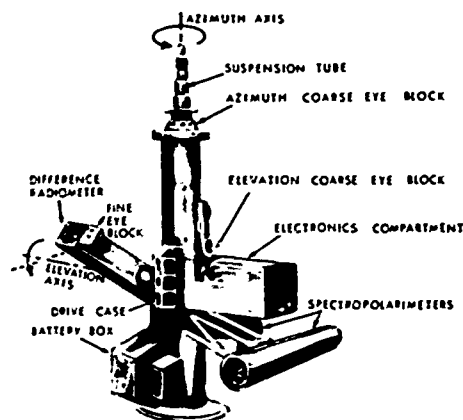


Figure 4. Principal Features of the Balloon-borne Flight (H68-35) Instrumentation Used by AFCRL for Atmospheric Optics Research

While the prototype of this infrared radiometer did gain numerical results, its initial use was to determine the feasibility of this general technique for future employment in an Aerobee rocket. The data substantiate the design except for some still unresolved low amplitude oscillations during the period of tropospheric penetration. Analysis of the data for intensity and polarization of the radiation emerging from the earth and atmosphere is not finished. Results of the measurements of polarization in the vertical plane, which includes the sun, do represent an almost purely molecular structure during the flight period. Indeed, the coincidence of actual data points with the theoretical formulation (Tables Related to Radiation Emerging from a Planetary Atmosphere with Rayleigh Scattering, by Coulson, Dave, and Sekera) is remarkable.

Analysis of the aerosol and atmospheric optics data acquired by Elterman of AFCRL with a balloon (H67-77) on 4 November 1967 was completed in January 1968. The flight data indicated that measurements were obtained from launch to about 15 km (above 80 percent of the atmosphere). A combination of instrumentation problems related to low pressure ionization (previously checked out), plus command link failure, prevented additional data collection. The data acquired was in the form of relative values, plotted for five scattering angles ($\phi_s = 25, 45, 90, 135, \text{ and } 155$ deg), two wavelengths ($\lambda = 0.40 \mu\text{m}, 0.65 \mu\text{m}$), and horizontal and vertical polarization. By application of the flight profile (time vs altitude) and calibration factors, the data were converted to absolute values of angular volume scattering coefficient vs altitude for each combination of polarization and wavelength, for each observation angle. From these results, plots of the volume scattering coefficient vs scattering angle were developed for altitudes of 2, 5, and 10 km. The measurements contained some interesting features, the most prominent being the variation of the aerosol content as a function of altitude. The angular scattering functions correspond to the general shapes that might be expected from a combination of aerosol and molecular scattering components, with the exception of the peak in back-scattering at approximately 140 deg (from interpolation) found in the vertical polarization curves at 5 km and above. These measurements are unique because of the variety of controlled parameters, spatial resolution, and altitude range. However, they should be considered preliminary because this is the first balloon effort of the program. Also, additional data is needed in order to perform dependable angular interpolation.

The AFCRL balloon nephelometer was again launched on 21 June 1968. During launch the automatic release mechanism was damaged, resulting in free-fall of the nephelometer shortly after launch with considerable damage to the instrumentation.

5.3.10 EARTH RADIANCE AND TRANSMISSION MEASUREMENTS

Rocket-borne measurements of the earth's limb radiance were continued in 1968 by Walker of AFCRL. One Aerobee sounding rocket instrumented with an active attitude-control system was launched on 15 August 1968 (AE3.725) from Churchill for infrared horizon definition studies. All instrumentation performed satisfactorily and 175 horizon crossings were obtained. Extremely interesting data were obtained by the airglow experiments and are being analyzed. The regions investigated during this flight included: the rotational water vapor bands between 19 and 35 μm and 22 and 35 μm ; the vibration-rotation bands of carbon dioxide centered at 15 μm with one bandwidth of 60 cm^{-1} and another of 80 cm^{-1} ; the "window" region between 10 and 12 μm ; the fundamental vibration-rotation band of ozone at 9.6 μm ; and broad band emission between 1 and 9 μm and 1 and 7 μm .

Additional experiments during the flight investigated the OH and O₂ airglow layers from dark and sun-lit atmospheric layers.

The vertical definition of the field of view for the horizon measurements is 13 arc minutes, resulting in a horizon resolution of 5 km. Stellar reference data

taken during the flight with AFCRL built stellar mappers provide information that will be used to determine the rocket attitude to 5 min of arc or less.

Walker plans to launch two Aerobee sounding rockets in 1969.

A single radiometer will be flown on the first flight for observations of the 15 μm CO_2 band and the rotational water band from 19 to 38 μm . A second radiometer will be used to investigate the OH and O_2 airglow layers as well as broad band infrared emission between 1 and 3 μm . The second rocket, with an instrumented radiometer, will be used to investigate two spectral regions centered around the 15 μm CO_2 region. A third channel will measure the water vapor emission at 6.3 μm and a fourth the 9.6 μm ozone emission. High resolution data is hoped to be obtained using helium cooled, copper doped, germanium detectors. Attitude determination of the rocket will be resolved to 1 min of arc using stellar mappers.

A comprehensive program of high altitude balloon probes was also supported by AFCRL during 1968. Instrumentation was designed, constructed, and flown by the University of Denver under the direction of AFCRL personnel. A total of 12 balloons were launched during the first 10 months of 1968; 2 for thermal flux measurements, 2 for solar constant determination, and 8 for transmission measurements. Table 2 summarizes the flights, all of which were launched from Holloman.

The solar constant was measured with Eppley normal-incidence pyrhemometers on three different days at 31 km altitude. After correcting the readings for the remaining 1 percent of the atmosphere, and the earth-sun distance, a value of 1.912 g Cal per cm per min was determined for the solar constant.

A comparison between the CO_2 telluric absorptions observed in high altitude solar spectra and those predicted on a theoretical basis indicates that the atmospheric concentration of CO_2 decreases above the tropopause. The concentration of CO_2 as determined by the 2.7 and 4.3 μm bands gives a value of 2.1×10^{-4} as the volume concentration above 17 km, as compared with the value of 3.3×10^{-4} for the surface concentration. The infrared solar spectrum in the 1.1 μm region was measured with a resolution of 0.50 \AA . The spectra indicate many new solar absorption lines that appear only at high altitudes where the telluric absorptions are eliminated.

5.1 Meteorology

5.4.1 DESIGN CLIMATOLOGY

Studies of atmospheric variability in the stratosphere and mesosphere were continued at AFCRL by Sissenwine and his group. All available temperature data obtained from the meteorological rocket network and experimental observations for levels between 25 and 60 km in the Eastern and Western Hemisphere have been compared to the temperature-height profile of the U.S. Standard Atmosphere, 1962, CIRA, 1965, and the USSR Standard Atmosphere 1964. The observations support

the U. S. Standard Atmosphere temperature-height profile as representative of mean midlatitude daytime conditions in the Northern Hemisphere between 25 and 50 km.

Table 2. Summary of AFCRL-University of Denver Balloon Probes

Date Launched	Wavelength Studied (μ m)	Experiment Carried	Peak Alt. (km)	Results
23 January (H68-3)	Total	Pyrheliometer-solar	30.2	Successful
29 January (H68-4)	8-12	Flux-broad-band	15.3	Partial success
22 March (H68-17)	4.5-20	Transmission	30.5	Successful
27 March (H68-18)	8-12	Flux-broad-band	31.4	Successful
19 April (H68-25)	8-12	Flux-broad-band	31.1	Instrument failure
24 April (H68-26)	2.7	Transmission	30.2	Partial success
26 April (H68-27)	Total	Pyrheliometer-solar	29.9	Successful
25 June (H68-42)	14-16	Flux-broad-band	29.9	Successful
	5-20	Flux spectrometer		
1 July (H68-45)	14-16	Flux-broad-band	31.1	Successful
	5-20	Flux spectrometer		
12 August (H68-55)	10-12	Transmission	31.1	Successful
8 October (H68-69)	8-12	Flux-broad-band	30.5	Partial success
10 October (H68-70)	16-21	Flux-broad-band	30.5	Successful

An AFCRL study of the spatial variations of wind over horizontal distances of 100 to 200 km at altitude levels between 20 and 70 km, based on wind data obtained from a series of 12 simultaneous ARCAS ROBIN firings (during 1967) from 3 locations on the West Coast, was prepared. Small scale oscillations in the observed wind profiles are interpreted as evidence of internal waves and are traced over horizontal distances of 200 km. Horizontal and vertical wave parameters are determined.

A special study of thin layer wind shear at 30 to 70 km indicates strong 1000 ft shears during March over Ascension Island at 60 to 70 km levels. For this layer thickness, shear values of 0.110, 0.150, and 0.170 per sec were computed from the data. From 161 soundings at Eglin Field, four values of shear ranging from 0.120 to 0.190 per sec were evaluated for 1 km layer thicknesses between 60 and 70 km. In both of these sets there was some suspicion that some of the shears may have been caused by ejection of the mylar balloon, which was tracked to get wind data, from the rocket. However, smoke-trail experiments made at Eglin suggest that strong shears do indeed occur at these altitudes.

Partial analysis of data from the rocket-launched, AFCRL Turbulence-Sensing Smoke-Trail Experiment in the 30 to 70 km altitude region has provided some rather startling results. Details of the experiment, conducted at the Eglin Gulf Test Range during November and December 1967, were reported on last year. Preliminary analysis of data indicates that vertical motions are present at all altitudes. The magnitude varies but large values occur both above and below the stratopause. Extreme motions are certainly larger than 5 m/s and probably as great as 15 m/s. The atmosphere at these altitudes is not homogeneous in the vertical, and it seems apparent that there are adjacent altitude layers in which the nature of the vertical motions are different. The exact reproduction of even the small-scale features seen on two side-by-side trails implies that vertical motions are not extremely localized and exist in the horizontal over at least 20 km, the separation between trails, and have a time duration greater than 4 min, the duration of analyzed data.

The driving force for these vertical motions is undetermined. However, the new theory of gravity wave instability may explain vertical motions of this magnitude.

A humidity profile depicting a nominal mid-latitude mean of the mesopause has been developed from results of 17 sea level to 32 km alpha-radiation hygrometer balloon soundings and data from noctilucent cloud experiments. Tables of these humidities, analogous to tables of the standard atmosphere, are under preparation.

5.4.2 METEOROLOGICAL ROCKETS

AFCRL launched 75 meteorological rockets during 1968 of which 66 were for system development purposes and 9 flights were for the development of sensing equipment.

The major emphasis at AFCRL in the meteorological rocket area continued to be on boosted-Dart techniques. A procurement of 975 LOKI-Dart instrumented vehicles for the Air Force, Army, Navy, and NASA was well underway at the end of the year. These vehicles, nomenclatured Meteorological Probe PWN-8B, have a nominal apogee altitude of over 65 km when launched from sea level at an 80 deg elevation angle, and they utilize a new and extremely stable STARUTE retardation device. Although the performance of the low-cost PWN-8B in the field has been very satisfactory, AFCRL initiated a development program to increase the capability of the boosted-Dart system. The modified system will be larger than the PWN-8B, with a 4-in. -diam motor, a 2.35 in. -diam Dart, and a larger STARUTE. A transponder payload under development will be incorporated into the system. Other advantages expected are a higher apogee altitude (75 km), slower descent rate, and elimination of the need for the relatively expensive ablative coating.

In December 1967 a series of 24 ARCAS meteorological rockets were flown to obtain measurements of the diurnal temperature variation; the rockets were equipped with a new thermistor mount that is less sensitive to radiation (solar and

thermal). The data from this series have shown a smaller diurnal temperature wave (3°C amplitude) at the ozone heating layer than previous results with the Arcasonde 1A and a much more pronounced phase shift with height.

Four series of flight tests were conducted with the high-altitude VIPER-Dart system. The development of this 140 km vehicle utilizing the ROBIN falling-sphere as a payload to measure density and wind data from 100 km down to 30 km is in the final stages. An earlier developmental version of the VIPER-Dart system is being used operationally for missile range support.

5.5 Geodesy and Gravity

5.5.1 SATELLITE GEODESY

The AFCRL program in satellite geodesy research for 1968 encompassed two main areas: the theoretical work and the experimental test work to support the theoretical research. In the area of theoretical studies, one of the most significant accomplishments was the development by Hadgigeorge of a method for computing the precise look-angle directions necessary for laser-satellite geodesy observations. The precise look angles are used to point the laser equipment at a point in space where the satellite will pass.

This look-angle technique has been perfected, and over the past 14 months Iliff of AFCRL successfully made daytime photomultiplier observations of laser reflections from the Explorer 22 satellite. This requires extremely precise aiming to permit the laser-beam angle to be narrowed, thereby increasing the radiant intensity and improving the probability of an observable reflection. In this observing method, no attempt is made to visually observe the satellite during a daylight pass.

In the area of experimental tests, Abby and Wirtanen developed techniques for making nighttime electro-optical detection measurements of satellite-borne beacons. For geodetic satellites equipped with on-board beacons, this technique permits photo-electric detection of the time of flash at the observing site; measurement of received pulse shape; and relative measurements of received light energy. The flash time measured at the ground can then be correlated with a photographic observation of the satellite for data reduction of the photograph. Heretofore, the only reliable precise flash time was the time of the flash as recorded by the satellite clock. All the other data on the photographic plate are referred to ground received time.

The measurement of the received pulse shape is a good indicator of the health of the flashing lights aboard the geodetic satellite. The pulse shape and light output characteristics are carefully measured and documented prior to flight. The measurement of the received pulse shape and energy relative to range and zenith distance are also indicators of atmospheric effects on satellite observations.

Another series of observations performed by Abby and Wirtanen show correlation between the fall-off of received energy and the increase in zenith distance. Indications are that the fall-off in received energy is in accord with the tailored beam characteristics of the geodetic satellites.

The ground reception time of satellite flash can be measured to a tenth of a millisecond with the existing equipment. Future plans for this particular experiment are to upgrade the frequency response of the photomultiplier receiving equipment to match the faster timing equipment.

A technique for worldwide clock synchronization using a synchronous satellite VLF transponder was developed and tested by Cook and Abby of AFCRL and by Gatterer of NBS for possible application to geodetic camera time synchronization problems. Time has been transferred via synchronous satellites using a two-way system where both master and remote stations transmit and receive time signals to an accuracy under $5\mu\text{sec}$. A study was conducted and tests made at AFCRL to determine if one-way transmission could be used to transfer time with an accuracy that would meet geodetic requirements. This would reduce the amount of equipment needed at a remote camera site to an antenna and receiver. The critical factor in one-way transmission is the path delay, and this was found to be predictable to within $10\text{--}60\mu\text{sec}$, thereby giving sufficient accuracy for satellite tracking. Future studies and tests are being planned by Cook, using channels in the UHF and X-band.

5.5.2 GRAVITY

Studies were performed under contract to AFCRL to best determine the structure of the external gravitational potential of the Earth by deriving the optimum method for combining satellite, terrestrial, and model gravity anomalies.

One form of a least-square combination of satellite and terrestrial data was investigated by Kaula in 1966. This method combined two sets of potential coefficients: one was the satellite estimates and the other was values computed by the usual summation process applied to a global terrestrial anomaly field. The new approach developed by Rapp of Ohio State University computes an anomaly computed from a set of potential coefficients found from satellite anomalies with the observed terrestrial estimate. It is shown that the results for the potential coefficients will only be the same when the anomalies have the same standard errors. Numerical tests were made with both methods by solving for potential coefficients to $n = 14$ and the adjusted $5\text{ deg} \times 5\text{ deg}$ field. The second method appears to be preferred when judged by the agreement of anomalies computed from the coefficients with actual terrestrial estimates.

5.5.3 ABSOLUTE GRAVITY REFERENCE

For the purpose of the correction of the "Potsdam" absolute gravity reference value, three absolute experiments were made during 1968 with the laser-interferometer absolute-gravity apparatus developed by Faller under AFCRL and NBS

support. Two of these three measurements were made in Europe, re-occupying Cook's site in Teddington, England, and Sakuma's site in Sevres, France. The Faller measurements agreed within 0.2 mgal with Cook's value and within 0.02 mgal with Sakuma's 1967 measurement. Additional experiments with the Faller apparatus and its comparison with other methods will continue in 1969.

5.6 Other

5.6.1 REENTRY COMMUNICATION STUDIES

Poirier and Rotman of AFCRL will conduct a microwave (S-band) transmission experiment with a Trailblazer II rocket to be launched from Wallops Island in May 1969. This experiment will extend the low-power, microwave-plasma, sheath-interaction studies of a previous rocket flight (AD21.860) to higher power levels at both the stagnation point and an expansion region in the gas flow about the reentry vehicle.

Laboratory studies of plasma alleviation techniques, using a plasma jet as a source of high-temperature gas flow, have demonstrated the efficiency of r-f heating and chemical additives, including fluorocarbon liquids, as a means of reducing electron density in the reentry flow fields, thereby improving vehicular communication links. Both of these alleviation techniques will be combined in a Trailblazer II payload to be flown in March 1970.

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Appendix A

AFCRL Rocket and Satellite Experiments - 1968

Table A1. AFCRL Sounding Rocket Experiments - 1968

Date (UT)	Time (UT)	Rocket Number	Launch Site	Approximate Altitude (km)	Experiment(s)
17 Jan	2308	AG7.634	Churchill	193	Atmospheric Winds, Density, Diffusion and Atomic Oxygen (Chemical Release)
19 Jan	2310	AG7.633	Churchill	191	Atmospheric Winds, Density, Diffusion and Atomic Oxygen (Chemical Release)
22 Jan	1320	AG7.635	Churchill	188	Atmospheric Winds, Density, Diffusion and Atomic Oxygen (Chemical Release)
19 Feb	1855	AH3.531	White Sands	242	Solar EUV (Monochromator, 230 to 1260 Å)
15 Mar	0710	AE7.290	Churchill	161	Magnetic Disturbance (Magnetic Field, Protons, Electrons)
1 May	2025	AH7.177	Eglin	217	Atmospheric Density (7-in. Falling Sphere)
2 May	0915	AG7.644	Vega Baja, P. R.	218	Barium Diffusion Rates (Chemical Release)
7 May	0900	AG7.643	Vega Baja, P. R.	225	Barium Diffusion Rates (Chemical Release)
13 May	0908	AH8.670	Vega Baja, P. R.	210	Barium Diffusion Rates (Chemical Release)
17 May	0900	AH7.571	Kaual, Hawaii	210	Atmospheric Density (Expandable Sphere)
20 May	1620	ESRO C42/1	Kiruna, Sweden	135	Micrometeorite Collection (Guest Experimenter)
22 May	2100	AH7.672	Kaual, Hawaii	201	Atmospheric Density (Expandable Sphere)
7 Jun	1520	ESRO C42/2	Kiruna, Sweden	128	Micrometeorite Collection (Guest Experimenter)
8 Jun	2100	ESRO C32/2	Kiruna, Sweden	142	Micrometeorite Collection (Guest Experimenter)
17 Jul	0130	AG7.881	Eglin	125	Atmospheric Composition (Only Langmuir Probe Data Obtained)
23 Jul	0408	AG7.628	Eglin	158	Ionospheric Winds (Chemical Release)
23 Jul	0418	AG7.629	Eglin	201	Ionospheric Winds (Chemical Release)
23 Jul	0423	AF7.389	Eglin	142	Atmospheric Composition (Positive Ion Mass Spectrometer)
23 Jul	0428	AG7.632	Eglin	150	Ionospheric Winds (Chemical Release)
23 Jul	0428	AG7.642A	Eglin	200	Ionospheric Winds (Chemical Release)
6 Aug	1845	AG3.532	White Sands	127	Solar EUV (Monochromator, 230 to 1260 Å)
8 Aug	1000	AG7.273	Natal, Brazil	157	Meteorite Dust Collection
12 Aug	1000	AG7.275	Natal, Brazil	153	Meteorite Dust Collection
15 Aug	0759	AE3.725	Churchill	179	Infrared Horizon Definition
19 Aug	0917	AG7.636	Churchill	177	Atmospheric Winds, Density, Diffusion and Atomic Oxygen (Chemical Release)
20 Aug	0800	AG8.649	Churchill	192	Atmospheric Winds, Density, Diffusion and Atomic Oxygen (Chemical Release)
20 Aug	0910	AH7.685	Churchill	175	Atmospheric Winds, Density, Diffusion and Atomic Oxygen (Chemical Release)
27 Aug	0334	AH7.667	Churchill	174	Atmospheric Winds, Density, Diffusion and Atomic Oxygen (Chemical Release)
27 Aug	0444	AH8.668	Churchill	201	Atmospheric Winds, Density, Diffusion and Atomic Oxygen (Chemical Release)
4 Sept	0204	AO7.913-1	Eglin	220	Atmospheric Density (7-in. Falling Sphere)
16 Sept	1550	AT3.170	White Sands	12	Engineering Test of Acrobac 170 Rocket
9 Nov	0855	AB19.287	Churchill	592	Magnetic Disturbance (Magnetic Field, Electrons, Protons)
19 Nov	0800	AG17.757	Churchill	129	Polar Cap Absorption Event (Ionospheric D-Region)
21 Nov	1830	AT3.533	White Sands	244	Solar EUV (Monochromator, 230 to 1260 Å)
9 Dec	2255	AH7.660	Eglin	124	Atmospheric Turbulence (Chemical Release)
9 Dec	2255	AF7.664	Eglin	117	Atmospheric Turbulence (Chemical Release)
10 Dec	1832	AG7.883	Wallops	122	Atmospheric Composition (Negative Ion Spectrometer, Langmuir Probe)
12 Dec	0245	AH7.887	Wallops	117	Atmospheric Composition (Negative Ion Spectrometer, Langmuir Probe)

Table A2. AFCRL Satellite Experiments - 1968

International Designation	Popular Name	Lifetime (Launch-Decay)	Experiments	Nominal Orbital Elements			
				Perigee (km)	Apogee (km)	Period (min)	Inclination (deg)
1968-014A	OGO-5	4 Mar 68	0 to 2.5 keV Ions and Electrons	270	148, 186	3, 705.9	31.1
1968-026A	OV 1-13	6 Apr 68	Cosmic Radiation Experiments	557	9, 317	199.6	100.0
1968-059A	OV 1-15 (SPADES)	11 Jul 68 - 6 Nov 68	Atmospheric Density and Composition	154	1, 809	104.8	90.0
1968-059B	OV 1-16 (CANNON BALL)	11 Jul 68 - 19 Aug 68	Atmospheric Density	149	568	91.68	90.0
1968-081A	OV 2-5	26 Sept 68	Geomagnetic Storms, Charged Particle Plasma Measurements, ORBIS High	Synchronous	29, 100	1, 417.4	2.918
1968-066B	Explorer 40 (Injun V)	8 Aug 68	0 to 2 keV Ions and Electrons				

Note: In addition, a total of 9 Cosmic Radiation (Nuclear Emulsions) Experiments were conducted on other satellites during the years 1967 and 1968 which have not previously been reported.

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Appendix B

AFCRL Rocket and Satellite Experiments Planned for 1969

Table B1. AFCRL Sounding Rocket Experiments Planned for 1969

Experimenters	Experiment(s)	No. Rockets	Launch Site
A. C. Faire	Atmospheric Density (Falling Sphere)	4 6	Eglin Churchill
G. Faucher	Atmospheric Density (Expandable Sphere)	5	Eglin
D. Golomb	Diffusion, Density and Temperature; Atomic Oxygen	5	Kauai
R. B. Harvey	VLF Ionosphere Propagation	2	Natal
H. E. Hinteregger	EUV Monochromator	4	White Sands
R. O. Hutchinson	Magnetic Fields	2	Churchill
A. J. LeBlanc	Atmospheric Absorption by Spectrometry	1	White Sands
J. McIsaac	Atmospheric Density (Bremstrahlung)	1	Eglin
R. S. Narcisi	Atmospheric Composition (Quadrupole Mass Spectrometer)	2 8 10	Wallops Eglin Churchill
N. W. Rosenberg	Ionospheric Winds; Barium Vapor Studies; CO ₂ in F Region	26	Eglin
W. Rotman	Re-entry Microwave Physics	2	Wallops
R. C. Sagalyn	Electric Fields and Structures	1	Churchill
S. Silverman	Aurora and Airglow	1	Eglin
R. Skrivaneck	Noctilucent Clouds	2 1	Churchill White Sands
A. T. Stair	IR Airglow	2	Churchill
J. C. Ulwick	Auroral Input-Output PCA Studies	8	Churchill
R. Vancour	Geomagnetic Fields	3	Churchill
R. G. Walker	IR Horizon	1 1 1	Natal White Sands Churchill

Table B2. AFCRL Satellite Experiments Planned for 1969

Spacecraft	Scientist	Experiment	Launch Site
ISIS-A	R. Narcisi	Positive Ion Composition (Two Mass Spectrometers)	WTR
	R. C. Sagalyn	Positive Ion Density and Temperature	
OGO-F	H. E. Hinteregger	Solar Spectrophotometry (EUV Monochromator)	Cape Kennedy
OV1-17	A. Barnes	Meteor Trail Calibration	WTR
	P. Newman	ELF in the Ionosphere	
OV1-17A	J. Mullen	ORBIS Cal II	WTR
OV5-6	K. Yates	Solar Flare Monitoring Satellite	Cape Kennedy

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Appendix C

AFCRL Space Science Bibliography - 1968

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